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Health Physics Department. Annual progress report 1 Januar - 31 December 1984

Risø National Laboratory, Roskilde

Publication date:
1985

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Risø National Laboratory, R. (1985). *Health Physics Department. Annual progress report 1 Januar - 31 December 1984*. Risø National Laboratory. Risø-M No. 2502

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Health Physics Department Annual Progress Report

1 January – 31 December 1984

Risø National Laboratory, DK-4000 Roskilde, Denmark
May 1985

Risø-M-2502

HEALTH PHYSICS DEPARTMENT
Annual Progress Report
1 January - 31 December 1984

Abstract. The report describes the work of the Health Physics Department at Risø during 1984. The activities cover dosimetry, instrumentation, radioecology, risk by nuclear activities and nuclear emergency preparedness. Lists of staff and publications are included.

The main emphasis in the report has been placed on scientific and contractual work. Of lesser importance, but still quite significant, are the service functions.

INIS Descriptors
DOSIMETRY; RADIATION PROTECTION; RADIOECOLOGY; RESEARCH PROGRAMS; RISOE NATIONAL LABORATORY

May 1985
Risø National Laboratory, DK-4000 Roskilde, Denmark

ISBN 87-550-1135-7
ISSN 0418-6435

Grafisk Service Center, Risø 1985

CONTENTS

1. GENERAL HEALTH PHYSICS

The Health Physics Department has the responsibility for some general functions at Risø: dosimetry, instrumentation, environmental monitoring, and health physics preparedness. The section for applied health physics, however, is part of the Safety Department.

More extensive education in health physics is also the responsibility of the department. Besides courses for the staff at Risø this includes shorter courses and lectures for nurses, fire brigade inspectors, naval officers and many others. Further, many of the staff members give lectures or otherwise assist in educational programmes at universities and give informative talks to societies and clubs.

For society at large, the department assists in answering questions and making statements or reports for the government and the central administration. Questions that relate to the Swedish nuclear power plant at Barsebäck, situated 20 km from the center of Copenhagen, have been of particular interest. The public concern about this plant led to the establishment of a Danish-Swedish Committee with the purpose of investigating the potential hazard to the Danish community in case of an accident at the plant. In 1983-84 the department answered several questions for this committee and provided information at some of its meetings.

Finally, it should be mentioned that the department is represented in a number of interntional committees, the most important of which are listed in Appendix 2.

2. DOSIMETRY AND INSTRUMENTATION

2.1. Personal dosimetry

Risø's personal dosimetry service covers the individual monitoring of the personnel at Risø and the Niels Bohr Institute Tandem Accelerator. All workers and visitors staying at Risø for a period of more than two days are supplied with the Risø standard beta/gamma personal TLD badge. Additional dosemeters, e.g. fast neutron films, quartz fibre pen dosemeters, extremity dosemeters and criticality dosemeters are supplied according to special requirements. Urine samples are routinely collected in accordance with an established programme.

In 1984 approximately 2300 persons were monitored; of these 202 persons received doses above the registration level for external doses of 0.2 mSv (20 mrem). The total dose (collective dose equivalent) registered to the monitored personnel was 0.38 man Sievert (38 man rem). 37 persons received internal doses caused by intake of tritiated water. The contribution to the total dose from internal doses was 0.025 man Sievert (2.5 man rem). Figure 1 shows the distribution of the levels of the registered doses for 1984.

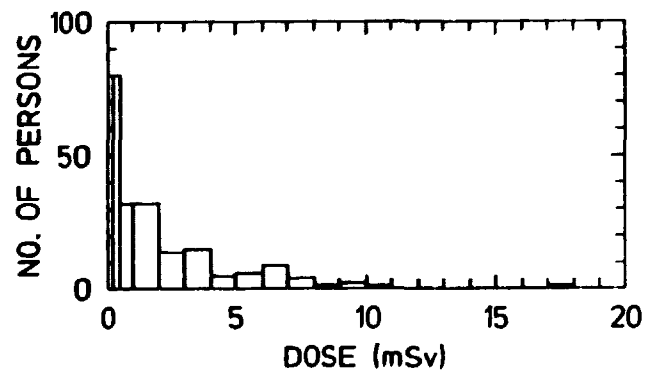

Fig. 1. Distribution of yearly whole body doses (effective dose equivalent) from 1984 for the Risø personnel.

2.2. Beta dosimetry

The energy- and angular dependence of the majority of currently used beta dosemeters presents a serious problem for personal monitoring of low-energy beta rays. A programme has been initiated analysing the influence of various parameters, e.g. detector thickness, filter thickness, detector area and detector/ filter geometry on the energy- and angular dependence of a beta dosemeter. The investigation comprises different types of thermoluminescent detectors with Mylar filters of thicknesses ranging from 0 to 75 $mg \cdot cm^{-2}$. The beta sources applied for the irradiations include ^{147}Pm, ^{204}Tl and ^{90}Y. A Perspex phantom that can be rotated to obtain different irradiation angles has been constructed. For standardising purposes, the measured TLD data will be compared with extrapolation-chamber measurements.

2.3. Studies of CR-39 nuclear track detectors

The response of CR-39 plastic to α-particles was studied as a function of α-particle energy and angle of incidence in connection with a master's thesis work. The characteristics of the passive radon dosemeter applied in the investigation of natural radiation (cf. section 2.4.) were further investigated. The sensitivity to radon and the background track density were determined for each individual sheet of plastic. Sensitivities varied between 5.1 and 6.1 cm^{-2} per $kBq \cdot m^{-3} \cdot h$ and backgrounds varied between 40 and 70 cm^{-2}. For each sheet of plastic three times the standard deviation of the background corresponded to a minimum detectable radon exposure within the range of 5-10 $kBq \cdot m^{-3} \cdot h$.

Neutron dosimetry studies with CR-39 track detectors were also continued. Calibrations are being performed with AmBe and Cf-252 neutron sources, and field trials have been initiated.

2.4. Investigation of natural radiation in Danish houses

A cup dosemeter has been designed and tested to be used in a subsequent nationwide investigation of radiation exposure in Danish dwellings. The dosemeter measures radon as well as external radiation. During the pilot survey described below the performance of the dosemeter has been satisfactory. The dosemeter was further tested in the Second European Radon Dosimetry Intercomparison organized in 1984 by the CEC in co-operation with the British NRPB.

Active measurements of radon and radon-daughter concentrations have been done with scintillation flasks and sequential counters. These instruments were tested at the above mentioned intercomparison. Furthermore, a semi-continuous radon monitor has been developed with the purpose of recording short-term variations in indoor radon concentrations. A prototype of this instrument has been tested with good results in our calibration room and in two detached houses.

Active measurements of external radiation levels have been made with a high-pressure ionization chamber (Reuter Stokes RSS-111) and a plastic scintillator instrument (Münchener Apparatebau 604.1).

The pilot survey of radiation levels in Danish dwellings comprised 82 dwellings of which 10 were flats and 72 single-family houses with one or two floors. Integrating measurements were made in three-month winter and three-month summer periods.

Dose rates from external radiation do not differ from winter to summer. The mean value for all dwellings is 0.09 $\mu Gy\ h^{-1}$. Minimum and maximum values are 0.06 and 0.13 $\mu Gy\ h^{-1}$, respectively. The mean dose rate for houses made of brick is 0.09

μGy h^{-1}. The corresponding values for concrete and wood houses are 0.08 μGy h^{-1} and 0.06 μGy h^{-1}. The active spot measurements of external radiation are in good agreement with the TLD results.

The results of the cup-dosemeter measurements of radon concentrations are shown in Fig. 2. There is a clear difference between the winter and the summer period for single-family houses and also between flats and single-family houses. The geometric mean values of Rn-222 [Bq m^{-3}] are

	winter	summer
single-family houses	90	53
flats	24	18

In single-family houses the controlling factors for radon concentration is ingress from the ground, air exchange and building materials. The ingress from the ground accounts for the generally higher concentrations in single-family houses than in flats.

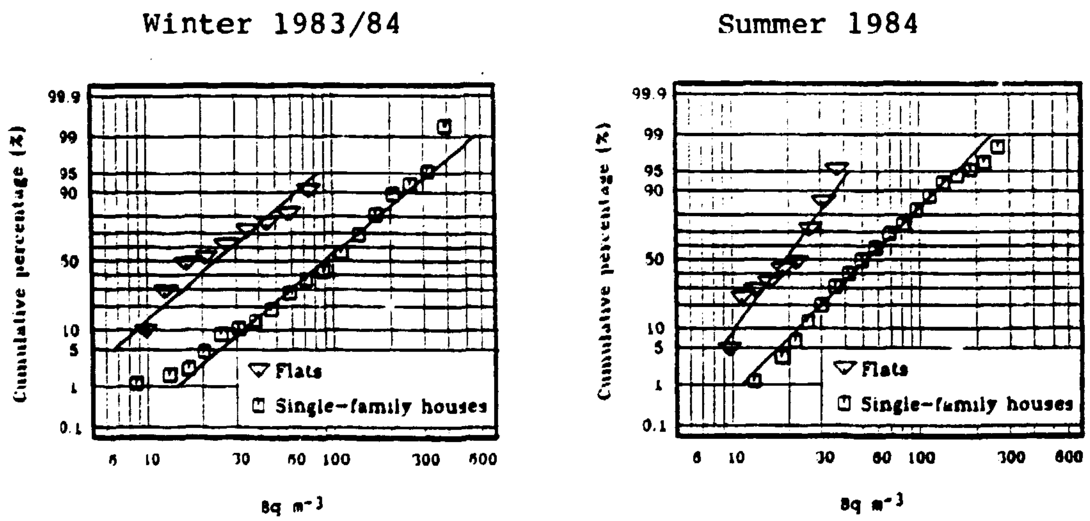

Fig. 2. Cumulative distributions of passive radon measurements.

During the winter the rate of exchange between indoor and outdoor air is kept rather low in Danish houses and the differences in radon concentrations between living-rooms, bedrooms and evén basement rooms are not significant, whereas significant differences are found in the summer period. The mean values are 55 Bq m^{-3} in living-rooms, 43 Bq m^{-3} in bedrooms and 82 Bq m^{-3} in basement rooms.

The simultaneous active measurements of radon and radon daughters have shown wide variations of the equilibrium factor, $F(= EER/C_R)$. In the winter period F ranges from 0.21 to 0.96 with a geometric mean value of 0.4. In the summer period the range is 0.05 to 0.78. The geometric mean is 0.2.

2.5. Epidemiologic investigations

The above-mentioned radon measurements seemed to indicate that the ratio of the average radon lung doses of Sweden to Denmark could be as high as 2. About 1/3 of all lung cancer cases in Sweden could be attributed to radon exposure according to the dose-effect relationship normally assumed.

On this background it was decided to undertake a comparative epidemiological investigation of the lung cancer burdens in Denmark and Sweden in the hope that a positive correlation between lung dose and lung cancer would be indicated. This turned out not to be the case. On the contrary the lung cancer burden in Denmark is about twice as high as in Sweden. This is true also for comparable sub-sets of the Danish and Swedish population. There is no corresponding difference in the extent of cigarette smoking. No other acceptable explanation for the discrepancy has been found.

2.6. Environmental dosimetry

As part of the environmental monitoring programme carried out by Risø, gamma background exposure levels at different sites in Denmark are routinely measured by means of LiF TLD-700 dosemeters. The integration times used are 6 months for zones surrounding the Risø facilities and 12 months for selected sites elsewhere in the country. The mean exposure levels, normalized to exposure rates, for different parts of Denmark in 1984 are given in the following table:

Location	Mean exposure rate (μR/h)*
Risø zones	8.6
Zealand and islands	8.1
Jutland	7.3
Bornholm (Baltic island)	11.5

*) cosmic component is included

Risø participated in an intercomparison programme on environmental dosemeters sponsored by CEC and NRPB, England. Dosemeters were exchanged between six laboratories in Europe and exposed to the respective local natural environmental gamma spectra. After evaluating the doses the work was discussed at a meeting in Brussels in 1984 and the results were reported in a joint NRPB report entitled "An Intercomparison Study of Thermoluminescent Dosemeters for Environmental Measurements".

2.7. Phantom for internal dosimetry

An internal-dosimetry phantom is under construction and it was nearly completed in 1984. It will be used for an experimental validation of internal dosimetry calculations for the Fisher-Snyder phantom.

Impressions have been made of real human organs and copies of the organs have been moulded. These copies have been used to produce vacuum forms, and plastic sheets have been sucked into the vacuum form producing a shell with a shape identical to the original organ. The same procedure has been used to produce the body and the extremities. The phantom has been supplied with lungs, liver, kidneys, spleen, stomach, GI-tract, bladder, pancreas, and thyroid gland.

To determine the importance of the density of the liquid to be used as body content in the phantom, experiments are in progress. Measurements have been made of dose rates in a target and a source cylinder of one litre volume, both submerged in different liquids. Tissue-equivalent liquid, water and alcohol have been used with radionuclides covering photon energies from 200 to 1400 keV.

2.8. Instrumentation

Risø health physics instrument service covers routine calibration and maintenance of approximately 650 health physics survey instruments of which approximately 50 are positioned outside Risø as part of emergency arrangements. In addition, the instrumentation group is responsible for the working and calibration of area- and effluent monitoring systems installed at nuclear facilities at Risø.

The 250-kV X-ray therapy unit installed for calibration purposes in the Health Physics Department was provided with a shutter device, and a testing programme was performed during 1984.

A gamma irradiation unit containing a 230 Ci ^{137}Cs source was designed and produced for the replacement of old ^{60}Co gamma calibration sources.

The department participated in a restricted intercomparison programme for environmental gamma monitoring instruments sponsored by CEC at PTB, Braunschweig. Among others, measurements were made in a 800-meter deep cave in the Asse saltmine having an ultra-low natural background of approximately 1.7 nGy per hour. Calibration experiments were carried out with various instruments in differently calibrated ^{137}Cs radiation fields.

2.9. Iodine/particulate effluent monitoring system

The new effluent monitoring system comprising 7 individual particle/iodine measuring channels installed in connection with the ventilation system at the Hot Cell plant was tested and a documentary report was published in 1984. It includes a detailed technical description, release criteria, and documentation for the iodine calibration.

2.10. Gas flow multicounters for low-level beta counting

The development of gas-flow counters for low level beta counting applications was continued in 1984 and resulted in a new and improved version of a 5-element GM multicounter system for the simultaneous counting of 5 samples. Two multi GM-counter for measuring of $^{90}Sr/Y$ and ^{99}Tc were produced and delivered to the Centre for Radiation and Nuclear Safety in Rovaniemi, Finland and the Bedford Institute of Oceanography in Canada, respectively.

Two systems comprising a total of 10 counting channels were delivered to the Nordic Laboratory for TL Dating for the determination of potassium in feldspars. A feldspar sample with a potassium content of 1% has been shown to yield a net beta count of 40 cph; the background is around 15 cph.

A new windowless gas-flow GM multicounter with four counting elements for measuring soft beta emitters was delivered to the University of Lund in 1984. Samples are placed inside the individual counter elements prior to sealing the counters and introducing a counter gas flow. The windowless 4-channel multicounter that operates with a common guard counter was initially developed to measure ultra-low energetic beta emitters such as ^{63}Ni samples prepared electrolytically on silver plates.

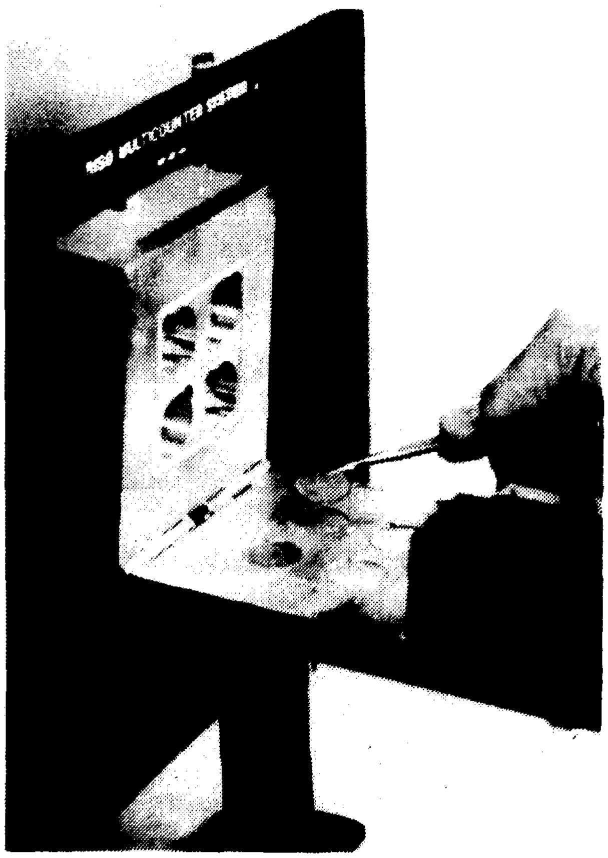

Fig. 3. New windowless gas-flow GM multicounter

2.11. TL instrumentation

Two fully automated computer controlled TL reader systems for TL dating were developed and delivered to the University of Oxford, England and the Lochranza Research Centre, Scotland. Both systems are controlled by HP85/86 microcomputers, enabling flexibility in selection of measurement parameters, calculation of TL signals and display and print-out of glow curves to be achieved. The completely new design incorporates a vacuum chamber that allows for the so-called fine-grain method to be performed. Software was developed accordingly to facilitate different special tasks within TL dating techniques.

2.12. Contamination monitor

A new contamination monitor for the simultaneous measurement of alpha and beta surface contamination was developed in 1984. The monitor is based on a gas flow proportional counter probe. Ten pieces were produced and delivered for the health physics control work at Risø. One monitor was delivered to the Danish Technical University.

List of publications

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CHRISTENSEN, P., Calibration of gammacell for blood irradiation", proceedings of the Nordic-Soviet meeting on standard and applied dosimetry, Helsinki 9-11 November, 1983, report STUK/A 50, p. 21 (1984).

GJØRUP, H.L. and HANSEN, H.J.M., Levetidstab fra lungecancer i Danmark og Sverige, Nordisk Medicin, Vol. 100 pp 100-103, (1985) (in Danish)

MAJBORN, B., Estimation of accidental gamma dose by means of thermoluminescence from watch jewels, Health Phys., Vol. 46, 917-919 (1984).

3. RADIOECOLOGY

3.1. Environmental radioactivity

The studies of environmental radioactivity were continued in 1984. Strontium-90 was determined in samples from all over the country of precipitation, ground water, drinking water, seawater, dried milk, grain, bread, potatoes, vegetables, fruit, total diet, and human bone. Furthermore, ^{90}Sr was determined in local samples of air, rainwater, marine sediments, grass, sea plants, fish, and meat. Cesium-137 was determined in air, precipitation, seawater, sediments, milk, grain products, potatoes, vegetables, fruit, total diet, sea plants, fish, and meat. Estimates of the mean contents of radiostrontium and radiocesium in the human diet in Denmark were given. Tritium was detemined in precipitation, fresh water and seawater. Plutonium and americium were measured in seawater, sediments, sea plants, and mussels.

The γ-background was measured regularly by TLD, ionization chamber and on site γ-spectroscopy at locations around Risø, at ten of the State experimental farms along the coasts of the Great Belt and around Gylling Næs.

The marine environment at Barsebäck and Ringhals were monitored for ^{137}Cs and corrosion products (^{58}Co, ^{60}Co, ^{65}Zn, ^{54}Mn).

Samples of various foods and drinking water from Greenland and the Faroes were analysed for ^{90}Sr and ^{137}Cs.

3.2. Uptake and loss of certain transuranium-, fission- and activation nuclides by Mytilus and Fucus

3.2.1. Introduction

The aim of this ongoing project is to contribute to a better understanding of the function of the seaweed Fucus Vesiculosus and the mussel Mytilus Edulis as bioindicators for long-lived anthropogenic radionuclides in waters of different temperature and salinity regimes.

The following nuclides have been included in the period 1981-84: $^{238}Pu(IV)$, $^{239}Pu(VI)$, ^{241}Am, ^{244}Cm, $^{237}Np(V)$, ^{155}Eu, ^{144}Ce, ^{134}Cs, ^{110m}Ag, $^{95m}Tc(VII)$, ^{65}Zn, ^{60}Co, $^{59}Fe(III)$, $^{54}Mn(II)$ and $^{51}Cr(III)$. The two plutonium oxidation states were produced according to Nelson & Lowett's method. All experiments have been performed with several nuclides simultaneously. The γ-emitters were measured directly by γ-spectrometry (Ge(Li)). The transuranics were measured by multielement α-spectrometry after an ion-exchange procedure and electroplating. Initial rates of uptake in Fucus measured after 24 hours were used to evaluate environmental parameters. Mytilus accumulation experiments were run under permanent low-level phytoplankton feeding in a turbidostatic set-up which has been further improved under this project. Long-term excretion studies with Fucus and Mytilus were performed at two field locations after the nuclides had been accumulated in the laboratory.

3.2.2. Fucus results

Initial rates of accumulation in Fucus is very different for different nuclides. In 9 experiments the following mean concentration ratios (Bq g^{-1} dry/Bq ml^{-1}) were found after 24 hours: Co: 1000, Zn: 1800, Cs: 70, Ce,Eu,Am,Cm: 2500, Np: 40, Pu(IV): 700. In a single experiment Pu(VI) showed a value of 250 and Tc: 4800. There is a pronounced variation with time.

Thus, the 9 experiments showed variations (S.D) of 30-60% for Pu(IV), Am, Np, Eu, Ce, Zn and Co, whereas the variation for Cs was only 15%.

The salinity effect on the accumulation after 24 hours (15 o/oo / 30 o/oo) was a factor 2.5 ($\pm$ 30%, S.D) for Cs, Ag, Zn, Co and Mn. The temprature effect (20°C/3.5°C) was 2.5 ($\pm$ 30%, S.D) for Cs, Zn and Co and a light effect (light/dark) of 4.4 ($\pm$ 15%, S.D) was recorded for Cs. There was no significant salinity effect for Ce, Eu, Am, Cm, Fe and Co; no temperature effect for Ce, Eu, Am and Cm and no light effects except as mentioned for Cs and in some experiments Zn and Co.

Most experiments have been done at pH ~ 7.8 (7.7-8.0). No effects were seen after lowering the pH to 7.3, whereas accumulation was slightly higher at pH 8.3 for Cs, Zn and Co.

It has been shown that all nuclides considered here are taken up and accumulated in all parts of the plants.

At two instances (winter 82-83 and spring-summer 84) long-term loss experiments were run with Fucus vesiculosus in Roskilde Fjord. After an initial loss, Zn, Co, Ag and Tc were lost very slowly ($T_{1/2b}$ > 0.5 year). For Cs a biological half-life of 35 days was recorded during spring, whereas it was twice as long during the winter. The lanthanides Ce and Eu were lost with a half-life of ~ 20d. All these biological half-lives were measured excluding growth dilution. During the spring experiment the biomass doubling time was measured as two months corresponding to a two-month half-life of activity concentration in the tissues. Loss of the α-emitters was studied in sections of plants sampled during the experiments. Results suggest that Cm, Pu(IV) and especially Pu(VI) are retained better than Ce and Eu. Thus, the two lanthanides are probably not usable as actinide-analogues in Fucus.

3.2.3. Mytilus results

A one-year excretion study was run in the Bothnian sea (5 o/oo salinity) at the Forsmark nuclear power plant and "biotest" area, Sweden, from October 1983. A distinct seasonal effect on loss rates was found. After the initial loss, most nuclides (Eu, Ce, Tc, Zr., Co, Mn) were apparently not excreted at all during the long, cold winter, whereas biological half-lives of 30-60 days were recorded for Mytilus soft parts during the next summer. Results for the α-emitters Pu(IV), Am and Np will appear later. In an accumulation experiment it has been seen that Am and Cm behave exactly similarly in seawater and mussels. Great variation between individual animals was identical for the two nuclides. Cm can therefore be used as Am-analogue when found feasible.

3.2.4. Models

The experimental results are being utilized in a model describing the function of Fucus and Mytilus as bioindicators for different nuclides under the influence of varying environmental conditions. Field results are available for comparison for several nuclides. The model will give an overview of the effects of environmental parameters, and can be used when deciding sampling-intervals in monitoring programmes. Thus it appears that Fucus gives a greater immediate response on peak-levels of ^{60}Co and ^{65}Zn during spring and summer, whereas a high level can be seen for several months from the autumn, but only for a few months if it appears in spring. The data also suggests that Mytilus might be a more stable bioindicator for lanthanides and perhaps also actinides than Fucus, as the content in Fucus is a balance between very rapid accumulation and loss. However, for nearly all elements Fucus has the highest concentration factor.

3.3. Studies of transuranic elements, radiocesium, tritium and ^{60}Co in seawater sediments, seaplants and mussels in the North Atlantic region

The North Atlantic region comprises in this project the waters around Greenland, the North Atlantic Ocean between Norway and Greenland, and the North and Baltic Seas (including the Danish Straits). In this region the salinity ranges from ocean water to brackish water, the climate from arctic to temperate. Although fallout nuclides from nuclear weapons testing in the atmosphere are still the main source of man-made radioactivity, the discharges of radionuclides from reprocessing plants in Western Europe contribute measurably to the radioactive contamination of the North Atlantic. At present the radionuclides ^{90}Sr, ^{99}Tc, ^{134}Cs and ^{137}Cs are detectable in the North, Baltic, Norwegian, Barents and Greenland Seas. The purpose of this project has been to study this contamination and in particular to use it as a tracer for waterborne pollution in general in the North Atlantic.

3.3.1. Main results obtained during 1981-1984

For the first time it is shown that radiotracers (^{134}Cs and ^{99}Tc), discharged to waters in western Europe can be found in Greenland waters, i.e. at distances more than 7000 km from their discharge point.

It is found that the transit time from Sellafield in the UK to the East Greenland Current at 80°-70°N is approximately 7 years, and that this estimate is in agreement with that obtained from oceanographic studies of a so-called salt anomaly in the mid-seventies in the North Atlantic.

From our radiotracer studies of the Sellafield effluent, we have measured that waterborne pollutants in the North Sea are diluted by a factor of 10 when they enter the Arctic Ocean with the West

Spitzbergen Current, and by a factor of 300-500 when they appear in the northern part (~ $80^{o}N$) of the East Greenland Current.

We have found indications of a short circuit in the Greenland Sea by which some high activity Atlantic water is transferred to the East Greenland Current at 70^{o}-$75^{o}N$. This means that the dilution factor from the North Sea to the southern part of the East Greenland Current is on the order of only 100.

It is shown that ^{99}Tc is a promising radiotracer over very long distances (~ 10^{4} km) in the ocean, when it is applied together with Fucus vesiculosus or Ascophyllum nodosum as bio-indicators. It is shown that enhanced discharges of ^{99}Tc began already in 1970 from reprocessing in Western Europe.

We have calculated transfer factors for ^{90}Sr and radiocesium to surface waters in various parts of the North Atlantic region (Bq m^{-3} per PBq discharged annually from Sellafield). The transfer factors of radiostrontium are twice those of radiocesium suggesting some sedimentation of the radiocesium.

Outside the North Sea the concentrations of $^{239,240}Pu$ and ^{241}Am are rather constant in North Atlantic surface seawater (12 mBq m^{-3} and 3-4 mBq m^{-3}, respectively). Enhanced concentrations of ^{238}Pu in the Norwegian Coastal Current and in the West Spitzbergen Current suggest, however, that minor amounts of plutonium from reprocessing in Europe may enter Arctic waters, but most of the transuranics are sedimented close to the sources.

From our field measurements of seaweed, mussels, fish and seawater we have determined the concentration ratios of biota to water in various parts of the North Atlantic region for ^{137}Cs and plutonium. For Fucus vesiculosus (dry weight) we have found, e.g., that the mean ratio varies between 180 and 480 for ^{137}Cs and between 6 000 and 40 000 for Pu. The mean concentration ratios for ^{137}Cs in fish (fresh weight) varied between 50 and 150, depending upon species and water salinity.

3.3.2. Sampling cruises

In 1984 there were expeditions to the Fram Strait, to West Greenland waters, to the Labrador Sea, the Thule district, and the Denmark Strait. Furthermore, throughout the period we have got samples every year from the Danish Straits, the Baltic Sea, the North Sea, the Faroe Islands and the Norwegian coastline. Occasionally, samples have been obtained from Svalbard, Jan Mayen and various locations in Greenland.

This programme would not have been possible without assistance and cooperation from: R/V Adolf Jensen, C.S.S. Baffin, R/V Dana, HMS Fylla, F/S Gauss, M/S Nella Dan, F/S Polarstern, M/S Smyril, F/S Walter Hervik and R/V Ymer and their respective institutions in Greenland, Canada, Denmark, Federal Republic of Germany, the Faroe Island and Sweden. Finally, the Institute for Energy Technology in Norway has assisted us with the sampling programme.

3.3.3. Development of procedures

During the programme we have developed a number of methods useful in marine radioactivity studies.

It is found that 100 g AMP precipitate approx. 65% of the radiocesium in 2 m^3 of seawater. We have further developed a field method where AMP is precipitated in 100 l water contained in a plastic bag; this method has been used at airborne expeditions to the Shetland Islands and Greenland.

A cheap, rapid and easy method has been developed by the University of Lund for determination of ^{99}Tc in environmental samples. The method use $^{99}Tc^m$ (half-life:6h) as a radiochemical yield monitor. Tc is extracted from sulfuric acid solution with tributylphosphate and back extracted with NaOH solution. ^{99}Tc is measured by an anti-coincidence shielded multi-GM gasflow counter developed and produced at Risø.

With a continously running peristaltic pump set to 400 liters per month we have collected water samples close to the Swedish nuclear power plant Ringhals and compared the water concentrations of ^{60}Co with those in monthly collected fucoids from the same locations. For a salinity of 20 o/oo we found for ^{60}Co a mean ratio of 4 x 10^4 of 1 kg (dry weight) of Fucus vesiculosus to 1 liter seawater.

3.4. Environmental studies of plutonium and americium at Thule, Greenland

This project deals with the contamination with transuranics from a nuclear weapon accident in 1968 at Thule in NW-Greenland. The aim of the project has been to study the behaviour of Pu and Am in the arctic marine environment and in particular to follow the distribution of these radionuclides in the sediments. The results may be applicable to the deep ocean disposal of low-level waste containing transuranic elements.

3.4.1. The 1984 expedition to Thule

In August 1984 we made our fifth expedition to Thule, this time on board the CSS Baffin from the Bedford Institute of Oceanology in Canada. Dr. John N. Smith was the leader of the cruise. We worked in the Thule area from August 7 to August 11, 24 hours a day. More than 100 samples were collected.

The main effort was to improve the sediment sampling. In addition to 17 stations established at earlier expeditions, we included 23 more preferentially in a 30-km long, deep trench, where we may see enhanced sedimentation of debris from the accident. We collected HAPS cores (13.5 cm$^{\varnothing}$ and 12-20 cm deep) and Box cores (going down to 40 cm). From the Box cores we took out subcores which will be analysed in 1-cm layers.

This will give an opportunity to determine the sedimentation rate and study bioturbation in more detail. The HAPS cores were sectioned in 3-cm layers.

Along with the Box cores we furthermore collected benthos. In some cases we also used van Veen grab samplers for benthic organisms. We caught a few fish, and seaweed were collected along the coastline.

Water samples were pumped up in 1800-liter containers, and Pu and Am were precipitated on board. A few 200-liter deep water samples were collected at the point of impact.

Beside the marine samples we got a few terrestrial ones by helicopter, mostly lichen and moss.

All samples will be analysed for Pu, Am and in case of sediments for ^{137}Cs and ^{210}Pb as well. Seaplants will be analysed for ^{99}Tc and ^{90}Sr, apart from γ-emitters and transuranics. We expect to have the main findings by 1985, but the total material will not be ready until 1987-88.

3.4.2. Intercomparison studies

One purpose of the joint Canadian-Danish Thule expedition in 1984 was intercomparison of sample equipment as well as of analytical procedures. A number of sediment and water samples collected at the expedition will be used in this exercise.

From Dr. V. Noshkin we have got two sets of North Atlantic deep sea sediments collected in 1982 at the NEA dumpsite for low-level radioactive waste. We found the same Pu inventories as Noshkin, but the vertical distribution of Pu in the duplicates differed probably due to bioturbation. We could confirm the conclusion of Noshkin that both cores contained global fallout Pu only.

We have furthermore made an intercomparison with Dr. Noshkin of our ^{241}Pu determinations on Thule samples. Our determination was made from reanalysis of old Pu counting samples in which ^{241}Am were analysed in order to determine the mother-product ^{241}Pu. Noshkin determined ^{241}Pu directly by mass spectroscopy. By the two methods we found a ^{241}Pu: $^{239,240}Pu$ ratio in the Thule debris as of January 1968 of 3.3 and 3.36, respectively.

Finally, we have participated in all the IAEA Monaco Laboratory intercomparison runs on marine samples.

3.5. Radiological consequences of the use of fly ash in agriculture

About one million tons of fly ash were collected in Denmark in 1983, and more in 1984.

Since fly ash typically contains nutrient elements and is supposed to improve the structure of certain types of soil, its use as a soil amendment in agriculture has been proposed.

Laboratory experiments were performed in cooperation with the Risø Agricultural Research Department in order to estimate the radiological consequences of the use of fly ash in agriculture.

Barley and grass (timothe) were grown in soil with 0, 25, 50, and 75 per cent fly ash added, and in pure fly ash, in order to estimate a possible correlation between the concentrations of ^{226}Ra, ^{210}Po, and ^{210}Pb in the crops and in the growth media. In addition samples of barley, fly ash, and soil from earlier field experiments were analysed.

No significant correlation was seen between the concentrations of the radionuclides in the growth media and the plants.

3.6. Membrane lipids in the eel affected by γ-irradiation and other environmental factors

The project aims to study the mechanism of salt transport in marine animals and how this mechanism is changed after high doses of γ-irradiation.

It has recently been shown in our laboratory that the $C_{16:1}$ fatty acid (palmitoleic acid) apparently plays a special role in the mechanism of salt transport by eel gills. This is in accordance with the general concept that the lipid moiety of the cellular membrane has a modifying effect on transport proteins. It seems reasonable to expect changes in membrane function to be accompanied by changes in lipid metabolism within the cell system involved.

The gills are known to be the main site of active salt transport (against concentration gradients) in fish. In the eel, there is further evidence of a hormone-regulated passive salt transport (along concentration gradients) in the esophagus. The fish intestine is regarded as the site of both active and passive salt transport.

Present experiments compare lipid metabolism (in vivo) in the gills, the esophagus, the intestine and the liver of the European eel (Anguilla anguilla). The liver acts as a reference tissue. Eels are kept in fresh as well as in seawater. They are caught either in their normal yellow stage or in their silver stage, which is when they are in a hormonal state ready for spawning migration from brackish water (Roskilde Fjord) to seawater. They are irradiated (10 Gy, total body) in a ^{60}Co-irradiation unit. Lipid metabolism is measured by adding ^{14}C-acetate and ^{32}P-phosphate as lipid precursors to the incubation tank. The various lipid classes from each tissue are separated and assayed by thin-layer chromatography. Fatty acids are separated and assayed by paper chromatography, after saponification and acidification.

Preliminary results show a common incorporation pattern of ^{14}C-acetate into the phospholipids of the intestine, the esophagus and the gills in seawater, which is significantly modified in the last two organs, but not in the first, when the animals are kept in fresh water. Phosphatidylethanol-amine is the main lipid affected by the change in environmental salinity.

During the past year we have also studied the effect of prolonged starvation (up to 2 years) on eel lipid metabolism in general. Is there perhaps a conversion from fat to carbohydrate in the starved animal? Preliminary results show a hormonal regulation that is difficult to assay.

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4. ELEMENTS OF RISK BY NUCLEAR ACTIVITIES

4.1. Gaussian model on atmospheric dispersion

The development of Risø's computer model PLUCON4 for calculating off-site consequences of releases of fission products to the atmosphere has continued.

PLUCON4 is used in a study of the sensitivity of dose pattern to grid size for population. This study is performed for the OECD/CSNI group GRECA. The preliminary results were presented on a GRECA meeting in Tokai, Japan.

Verification of the dose models included in PLUCON4 has continued. A report on the comparison of PLUCON4 calculations with data from tracer experiments at the Swedish nuclear power plant Ringhals is due in 1985.

4.2. Puff model

A new model PUFFCON is being developed for calculating the consequences of accidental releases taking into account the variation of the meteorological conditions with time. This model is based on a puff dispersion model. It is a three-dimensional computer model which simulates the release of pollutant puffs and predicts their concentration as they diffuse while being advected downwind by a time- and space-dependent windfield.

Calculation of external gamma doses from airborne as well as deposited radioactivity will be included in the model. Thus, the final model will be able to calculate collective doses, consequences, etc.

The computer programs for calculating concentrations of airborne material and for graphical presentation of calculational results have been further developed.

The development of a prototype dose/consequence model based on the puff model and the WASH1400 consequence code CRAC2 has started. This work will be completed in 198. The project is financed by the Nordic Council of Ministers and the new model, PUFFCRAC, will be made available to all Nordic countries.

Validation of the puff model using results from experiments performed at Kernforschungszentrum Karlsruhe (KfK) has started. This is a part of a cooperative programme between Risø and KfK in relation to phase two of the German risk study.

4.3. Radiological consequences of accidental contamination in urban environments

The areas for which major uncertainties exist for predicting radiological consequences of accidental releases of radioactivity especially concern the urban agglomerations. Under a subcontract with Euratom-CEA, Risø has developed a comprehensive methodology taking into account the most recent experimentally derived parameters, in order to enable more accurate dose predictions to be made.

4.3.1. Dry deposition

A literature review has revealed very little work on deposition in urban areas. Indeed, most accident models use the same deposition velocity in urban and in rural areas.

Beryllium-7 created by cosmic radiation and fallout cesium-137 was used as tracers in measurements designed to find the dry deposition velocity on building surfaces.

The deposition velocity of cesium is found to be in the range 0.005-0.04 $cm \cdot sec^{-1}$, and the deposition velocity of beryllium 0.001-0.07 $cm \cdot sec^{-1}$. The deposition velocities are found to be in the same range for vertical and horizontal surfaces.

These deposition velocities indicate that the deposition velocities in urban areas are considerably smaller than those in rural areas.

A continued effort is needed to clarify the deposition processes in urban areas because of the importance of the deposition velocities in accident calculations.

4.3.2. Wet deposition

Precipitation might effect the deposition to a very considerable degree. Therefore, a 4-year-old literature review by O.J. Nielsen has been updated. The literature contains a good deal of theoretical work and many reviews. Unfortunately, very few measurements are reported, most of them concern rain scavenging of particles. Furthermore, the results spread over several decades. Therefore, it does not seem worthwhile to invest in new theoretical work before more data are compiled.

4.3.3. Run-off

Run-off is that excess of contaminated rain water that does not remain on the area receiving the rainfall. This phenomenon has been extensively studied in the context of hydrology and from these studies data for run-off from urban surfaces are available. In most models it is assumed that the concentration in the run-off water is equal to that in the rain water.

Experiments with the aim of examining this assumption were done at Risø with the use of beryllium-7 and cesium-137 as tracers. A roof construction was built with different roof materials and with slopes of 30° and 45°. For various roofing materials the run-off effect was shown to be very different. Less contamination remains on silicontreated material than on porous red-tile roofing material. Cesium is more affected by run-off than beryllium.

Measurements on old material indicated that 44-86% of the cesium is carried away by run-off processes whereas those on new material gave a figure of only 31-50%.

The measurements will be continued in order to confirm the results and to study the dependence on rain intensity.

4.3.4. Weathering

Radioactive material deposited on outdoor surfaces is gradually removed under the influence of the weather. This process is generally called weathering. In most accident models, the well-known Gale formula is used to take account of weathering, but it is valid only for rural areas. Several experiments of weathering of fission products on urban surfaces are in progress, but only few are reported.

Recent experiments at Risø have indicated that for concrete as well as asphalt roads new surfaces are more "contamination repellant" than old ones. Also, proportion of the contamination removed by weathering within the measuring periods of 80 to 160 days was measured to reach 0.5 for a new concrete surface and 0.6 for a new asphalt one. While an old asphalt surface did not show any signs of weathering, an old concrete surface showed a removal of 0.4.

Many parameters such as meteorological conditions, surface proporties, and particle size influence the weathering process and more experiments will be needed to improve the knowledge of it.

4.3.5. Shielding factors

Building structures provide a shielding effect for people staying indoors.

During the last twenty years there has been a steady decline in new research on shielding factors for gamma radiation from activity deposited on structures and ground surfaces. Most of the shielding factors used today - including those used in the WASH-1400 and the German Reactor Safety Studies - are based on calculations made with the so-called Standard Method. Although this method gives results that agree well with experiments, there was a need for methods that more rapidly can calculate shielding factors for different building types.

Shielding factors for gamma radiation from activity deposited on structures and ground surfaces were calculated for single-family and multistorey buildings in France, United Kingdom, and Denmark. For all three countries it was found that the shielding factors for single family houses are approximately a factor of 2-10 higher than those for buildings with five or more storeys. Away from doors and windows the shielding factors for French, British and Danish single-family houses are in the range 0.03-0.1, 0.06-0.4, and 0.07-0.3, respectively. In WASH 1400 a shielding factor of 0.2 was used based on an assumed average for American buildings.

4.3.6. Reduction of inhalation doses by staying indoors

The inhalation doses by staying indoors are affected by the filtering effect of the buildings, the deposition velocity indoors and the ventilation rate. However, very few accident models have taken these effects into consideration.

Several studies of the indoor-outdoor air pollution relationship are carried out assuming normal habits incl. ventilation etc. Only a few of the studies consider situations where the ventilation has been stopped and windows and doors closed during the passage of the plume, although this is generally accepted as the first public countermeasure in case of a reactor accident. A literature study showed that the protection factor for reactive matter is higher than for non-reactive particles.

Experiments were carried out using naturally generated beryllium-7 and sulfurhexaflouride as tracers in order to estimate the protection factor for inhalation by staying indoor with windows and outside doors closed during a plume passage in comparison to that by staying outside. For a normal living room of about 50 m^3, the protection factor for particles was found to be about 3. Operating a vacuum cleaner during the period when staying indoors will increase this factor to about 9. Airing in one hour after the passage of a plume of three hours duration will raise these two factors to 6 and 12, respectively.

The only way to obtain protection from a non-reactive gas is by controlled airing. Under the above mentioned condition, airing will give a protection factor of 2.

Because of the great influence of this effect it would be desirable to extend the measurements to other dwellings than the 17 measured in this study.

4.3.7. Forced decontamination

In order to reduce the collective dose commitment or limit the duration of a relocation, it might be appropriate to take some decontamination actions.

The efficiency of a decontamination depends on parameters such as type of surface, time and means available. The decontamination factor is defined as the ratio of the contamination level before action to the level after. Decontamination factors for forced decontamination of urban surfaces vary significantly according to literature. A factor of up to 2 is reported by Risø for firehosing roads, whereas removing a surface of limited area can bring the contamination level down to the background level.

WASH-1400 used for urban areas factors of 2 or 20, dependent on cost; exsperiments conducted at Risø showed a factor of 2-5 to be more realistic.

4.4. Work for the Danish Utility Groups Elsam and Elkraft

In co-operation with the two utility groups, the ongoing work has been finished in connection with the application for site approval for three sites, Gylling and Glatved in Jutland and Stevns on Zealand.

One section in the application concerned with radioactivity releases describes the consequences of unit releases of radioactivity in terms of terrestrial doses in the environment within distances of 50-60 km from the plants. Another section describes the consequences from radioactivity released from a BWR plant during normal operation in one year as well as from four specified accident sequences.

The PLUCON4 model was used for the calculations. As a basis for the calculation of the collective doses in these sections, an update of the Risø population distribution data base has been made. The data base provides information on the resident population at each 1 km x 1 km square net as defined in the OTM-system. The earlier version of the data base was worked out in 1976-1978.

The information now available gave rise to corrections in the data base for the 1992 prognosis especially in the metropolitan Copenhagen area. Here the 1976-78 data were ca. 9 % underestimated in the Copenhagen and Gentofte communities. Minor corrections were further made at a few other areas in eastern Zealand, where the figures for the population distribution were overestimated.

4.5. Work for the Swedish-Danish Barsebäck Committee

Supplementary calculations of the consequences of hypothetical accidents at the Swedish nuclear power plant Barsebäck situated 20 km east of Copenhagen and a note on dry deposition velocities has been made for the Barsebäck committee.

The committee also suggested in 1983 that a demographic comparison of the Barsebäck nuclear power plant be made with similar plants situated near other large cities and national borders.

Sixteen other nuclear power plants: 13 in Western Europe, 2 in USA, and 1 in Canada were chosen for the comparison. Within five discrete distances out to 50 km, the population distributions have been found and compared.

In addition the positions, relative to the power plants, of institutions, administrative centers, communication centers, and other public establishments within the country or in neighbouring countries are described.

Of the sixteen plants investigated, ten are placed closer to neighbouring countries than Barsebäck, all of them have more inhabitants than Barsebäck within a distance of 10 km and six of them have more inhabitants than Barsebäck within a distance of 50 km.

Included in the report is a review of special agreements or negotiations between neighbouring countries or internationally about nuclear power-related matters. These include alarm and emergency procedures and agreements about liability in case of an accident in a neighbouring country.

In April Walmod participated in the committee's study tour to Switzerland.

4.6. Tokamak thermonuclear reactor

Early recognition of safety problems with a Tokamak fusion reactor will provide the opportunity to reduce these problems by improving design and materials.

Using a computer model of a fusion reactor is one of the ways to evaluate these problems and to calculate the consequences to public, operating personnel and the environment. With a computer model it will be reasonably easy to recalculate the consequences when the design and/or the materials are modified.

The Monte Carlo code MCNP version 3, has been used to create a three-dimensional mathematical model for studies of the exposure rate level from neutrons as well as gamma rays from the activated materials, and for later estimates of radiation doses to the personnel that might have to enter the reactor hall after an accidental event.

A simple model representing 1/12 of a Tokamak fusion reactor has been developed. The model is based on the recommendations from the INTOR workshops.

4.7. Next European Torus (NET)

For a European working group on safety and environmental aspects of NET (Next European Torus), Risø has prepared guide lines for the radiological safety.

List of Publications

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5. NUCLEAR EMERGENCY PREPAREDNESS

5.1. Risø

The external emergency plan for radioactivity accidents at Risø National Laboratory was partially revised in 1984. An alarm procedure parallel to that in the Barsebäck emergency plan has been implemented.

5.2. Barsebäck Power Plant

Under the existing co-operation on the Barsebäck emergency plan with the Danish Environmental Agency, an implementation of computer technique in the emergency communications system is being developed. Two identical computers (HP 9836CU) are installed at the police headquarters in Copenhagen and at our department at Risø. A terminal installed at the civilian defence forces station at Hillerød provides a third possible input station for field measurements. Other authorities have shown interest in the system.

A data base of the population distribution of Zealand and the southern part of Skåne has been implemented for consequence calculations. Also a data base of detailed demographic mapping has been introduced in the system, allowing a zooming option to be utilized.

5.3. Work for the Swedish State Radiation Institute (SSI)

In 1982 a disperison- and dose library called KASSANDRA I were made. The calculations covered BWR2 and BWR3 releases as defined in WASH-1400 within a distance of 70 km. The size of the reactor considered was 580 MW_e, equal to either of the two Barsebäck reactors.

A new edition called KASSANDRA II was made in 1984. The calculations include a BEED-release (defined in Risø-M-2299) from a 580-MW_e reactor, and a PWR4-release (from WASH-1400) from a 820-MW_e reactor of the Ringhals type.

In the new library, mixing layer and different deposition velocities for different isotope-groups are introduced. Therefore, the two libraries are difficult to compare.

5.4. German Democratic Republic

In September, Walmod took part in expert talks in East Berlin concerning emergency procedures and environmental protection in Denmark due to the Greifswald nuclear plant on the Baltic coast.

The GDR representatives reconfirmed a statement from 1980. According to which Danish authorities will be informed in case of an off-site emergency being declared at the site.

Further talks are to be held in 1985 and a Danish visit to the power plant is planned.

Appendix 1.

STAFF OF THE DEPARTMENT

Scientif Staff

(number refers to the relevant sections of this report)

Boelskifte Petersen, S. (3)
Bøtter-Jensen, Lars (2)
Christensen, Poul (2)
Dahlgaard, H. (3)
Gjørup, H.L. (Head of the department)
Hansen, Heinz (3)
Jensen, Per Hedemann (2,4)
Lauridsen, Bente (2,4)
Lippert, Jørgen (2,3,5)
Majborn, Benny (2)
Meide, Annelise (3,4)
Nielsen, Flemming (4,5)
Nielsen, Sven P. (2,4)
Roed, Jørn (4)
Sørensen, Arne (2)
Thykier-Nielsen, S. (4,5)
Vinther, F. Heikel (4,5)
Walmod-Larsen, Ole (4,5)
Warming, Lisbeth (4)
Aarkrog, Asker (3)

Technical Staff

Ahleskov, Eva
Berg, Birthe
Bitsch, Gunnar
Brandstrup, Oda
Brisson, Steen
Brøns, Per A.

Baade-Petersen, Pearl
Christensen, Tove
Christiansen, Henrik
Clausen, Jytte
Ebling, Elise
Frost, Ellen Margrethe
Hansen, Elly
Hansen, Lissie Sture
Holm, John Hammer
Hougaard Henrik Pedersen
Jensen, Karen Mandrup
Jensen, Rita S.
Jensen, Svend Åge Winfeldt
Jepsen, Johs.
Jørgensen, Finn
Jørgensen, Vibeke
Kjølhede, Alice
Lange, Rolf
Larsen, Tommy Bomand
Madsen, Anna
Mundt, Helge Chr.
Olsen, Signe
Pedersen, Anna Holm
Pedersen, Finn
Porsdal, Helle
Prip, Henrik
Rabe, J.H.
Roig, Joaquin
Sørensen, Else Marie
Sørensen, Lis
Wartenberg, Niels
Wie Nielsen, Karen
Willumsen, Finn

Office Staff

Christiansen, Ulla Riis

Kristensen, Ingrid

Nielsen, Margit

Ullrich, Elisabeth

Appendix 2.

PARTICIPATION IN INTERNATIONAL WORKING GROUPS, etc.

IAEA, The International Atomic Energy Agency

Advisory Group on Post-Accident Assessment and Recovery Operations in a Radiation Environment (Hedemann Jensen).

OECD, Nuclear Energy Agency

Committee on Radiation Protection and Public Health (Gjørup)

CSNI: Principal Working Group IV (Gjørup)

do. Subgroup of Experts on Accident Consequences (Thykier-Nielsen)

CSNI: Working Group on Fuel Cycle Safety (Roed)

Executive Group for Research on Sea Disposal of Radioactive Waste (Aakrog)

do. Radiological Surveillance Task Goup (Dahlgaard)

Commission of the European Communities

Article 31 Committee, Basic Safety Norms (Gjørup)

Article 37 of the Euratom Treaty, Group of Experts (Walmod-Larsen)

ACPM, Biology - Health Protection, from 1.1. 85 CGC on Radiation Protection (Gjørup)

Study Group on Accident Consequence Assessment (Gjørup)

do. Expert Group C on the Atmospheric Fission Product Dispersion following a Reactor Accident (Thykier-Nielsen)

Expert Group on Safety and Environment for the European Fusion Programme (Warming).

Expert Group on Transfrontier Emergency Planning (Walmod-Larsen)

Group of Technical Experts on Radiation Protection Dosimetry (Christensen and Majborn)

EURADOS, Beta- and Low-Energy Photon Dosimetry (Christensen)

<u>European Atomic Energy Society:</u>

Public Relations Correspondents Group (Walmod-Larsen)

<u>International Committee for Radionuclear Metrology</u> (S.P. Nielsen)

<u>Nordic Cooperation:</u>

Nordic Executive Group for Radioecology (Aarkrog)

SNODAS (coordination of Nordic dose calculations and atmospheric dispersion models) (Hedemann Jensen, Thykier-Nielsen)

Risø National Laboratory **Risø - M - 2502**

Risø - M - 2502

Title and author(s)	Date
Health Physics Department Annual Progress Report 1 January - 31 December 1984	May 1985
	Department or group Health Physics Dept.
	Group's own registration number(s)
48 pages + tables + illustrations	

Abstract

The report describes the work of the Health Physics Department at Risø during 1984. The activities cover dosimetry, instrumentation, radioecology, risk by nuclear activities and nuclear emergency preparedness. Lists of staff and publications are included.

The main emphasis in the report has been placed on scientific and contractual work. Of lesser importance, but still quite significant, are the service functions.

Copies to

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